Dynamic Coherence Law: A Time-Evolution Formalization of Bounded Persistence

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Abstract

This paper extends the Unified Coherence Formula into a dynamical law governing persistence in finite systems. It formalizes the relationship between divergence (Δ), irreversible accumulation (K), and finite resolution capacity (ρ) as a time-evolving constraint. The result is a bounded load evolution model in which stability, saturation, and collapse emerge as necessary structural states. The formulation integrates relational ontology, irreversibility, and capacity limits into a single persistence condition that applies across cognitive, computational, biological, and physical systems.

1. Foundational Axioms

A1. All non-trivial systems are relationally defined (state exists only relative to interaction).
A2. All non-trivial systems accumulate irreversible load over time.
A3. All systems operate under finite resolution capacity.
A4. Persistence requires that total structural load remains bounded relative to capacity.
A5. Identity is preserved only through invariant constraints.

2. System Definition

Let $S = (M(t), E(t), I, K(t), \rho)$

$M(t)$: internal model state of the system
$E(t)$: external environment state
I: invariant set preserving identity
$K(t)$: cumulative irreversible load (monotonic)
ρ: finite resolution capacity

Define relational divergence:
$\Delta(t) = || \Phi(M(t)) - \Phi(E(t)) ||$
(the structural mismatch between the system's internal model and its environment)

Define total structural load:
$L(t) = \Delta(t) + K(t)$
(the combined burden of mismatch and irreversible accumulation)

Define normalized stress:
$\Sigma(t) = (\Delta(t) + K(t)) / \rho$
(the proportion of total load relative to system capacity)

3. Structural Classification

Coherent if $\sup \Sigma(t) < 1$ (load remains within capacity)
Saturated if $\sup \Sigma(t) = 1$ (system at capacity limit)
Collapsed if $\sup \Sigma(t) > 1$ (load exceeds capacity)
Undefined if $\exists t$ such that $\chi_I(M(t)) = 0$ (invariant violation → identity loss)

4. Dynamic System

$d\Delta/dt = \eta(t) - u(t)$
(divergence increases through disturbance η and decreases through correction u)

$dK/dt = \alpha \cdot u(t) + \kappa(t)$
(irreversible load increases through correction cost $\alpha \cdot u$ and background accumulation κ)

Constraint:
$0 \leq u(t) \leq \rho$
(correction effort is bounded by finite capacity)

Total load evolution:
$dL/dt = \eta(t) + \kappa(t) + (\alpha - 1)u(t)$
(net change in total burden over time)

5. Invariant Dominance

Let $\chi_I(M(t)) = 1$ if invariants are preserved, else 0.
If $\chi_I(M(t)) = 0$ at any time, the system becomes Undefined.
Invariant violation supersedes all load and stress conditions.

6. Stability Structure

Define Lyapunov candidate:
$V(t) = L(t)$
(total structural load as a measure of system stability)

If:
$dV/dt \leq 0$
(load does not increase over time)
Then the system remains bounded and persists.

7. Core Theorems

Stability Theorem:
If $\langle dL/dt \rangle \leq 0$ and invariants hold, then $\Sigma(t)$ remains bounded and the system persists.

Saturation Theorem:
If $L(t) \to \rho$, then $\Sigma(t) \to 1$ and the system reaches its structural limit.

Collapse Theorem:
If $\exists t$ such that $dL/dt > 0$ under maximal correction $u = \rho$, then $L(t)$ increases and collapse is inevitable.

8. Collapse Inevitability Condition

Under maximal correction $u = \rho$:
$dL/dt = \eta(t) + \kappa(t) + (\alpha - 1)\rho$

If:
$\eta(t) + \kappa(t) + (\alpha - 1)\rho > 0$

Then:
$dL/dt > 0 \rightarrow L(t)$ increases $\rightarrow \Sigma(t) \rightarrow 1 \rightarrow$ collapse

9. Framework Integration

This law integrates the Relative Framework components:
- RCN: provides correction dynamics u(t)
- TSDT: provides stress classification via Σ
- Coherence Formula: defines persistence boundary

This formulation defines how systems evolve relative to that boundary over time.

10. Non-Reduction Statement

Removal of divergence (Δ), irreversibility (K), capacity (ρ), invariant constraints (I), or dynamic evolution breaks the structural integrity of the system. These components are interdependent and non-separable.

11. Conclusion

The Dynamic Coherence Law establishes persistence as a bounded process governed by the relationship between divergence, irreversible accumulation, and finite capacity. Systems do not remain stable by default; they persist only through continuous regulation of structural load. When total load remains within capacity, the system maintains coherence. When load approaches capacity, the system saturates. When load exceeds capacity, collapse follows necessarily. This condition is not domain-specific. It applies uniformly to cognitive systems, artificial agents, biological organisms, and physical processes. The form of the system changes, but the constraint does not. Persistence is therefore not equilibrium. It is bounded survival under irreversible pressure. This defines bounded load evolution as a necessary condition for the existence of any finite system.

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